Facial Feature Detection: A Facial Symmetry Approach

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Abstract—**Nowadays face detection plays an important role in recognition, emotion recognition, computer-human interaction, etc. This paper presents a novel method for the detection of facial features in images. The main objective is to develop a fully automatic facial feature detection system. The method proposed in this paper uses a combination of methods to detect facial features. It first uses the Viola-Jones methods to identify possible regions of interest subsequently use calculations based on the symmetric property of the human face to detect the true facial features. A comparison between the Viola-Jones algorithm and the proposed algorithm has been performed and it shows that our method in combination with Viola-Jones increases the accuracy of detection considerably.**

Keywords- facial feature detection; Viola-Jones; image processing;nose detection;mouth detection;eyes detection; artificial intelligence;machine learning

I. INTRODUCTION

Face detection can be dated back to the 1970's,[1] however due to recent advancement in technology a lot of work is being done in this field [2][3][4][5]. Facial Feature detection has become very crucial to be able to detect human faces in images and video due to the current circumstances and its application in fields such as traffic safety, visual surveillance and human computer interaction.[6] Due to high demand for automatic human detection, it has become very important to build a fully automated system to detect human faces and facial features to be used in the real world.

Facial detection technique can be broadly divided into two types feature based and image based. The feature based techniques can be further divided into active shape models, low level analysis and feature analysis. Low level analysis uses features such as skin colour [7], edge detection [8], motion in frames [9] and grayscale images [10] for face detection. Feature analysis aim at finding structural features of the face to detect a face in an image. A couple of well known feature analysis methods are Viola Jones method and Gabor Method.

The Gabor method [11] uses the Elastic Bunch Graph Map (EBGM) algorithm that uses gabor filters for face detection. The EBGM method uses 40 different gabor filters to produce 40 different images with different angles and orientation. Fiducial points are found out from the filtered images. The result of applying gabor filters on an image is shown in fig. 1

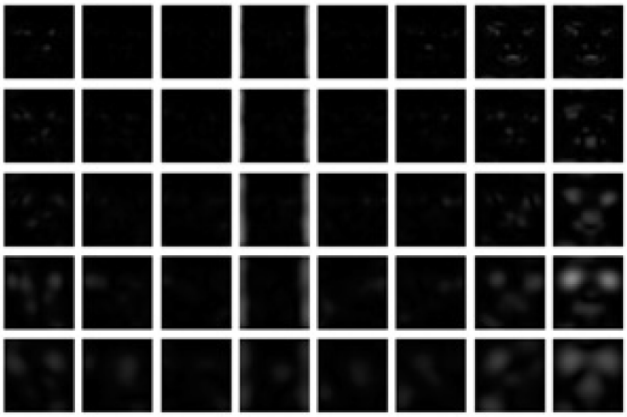


Figure 1. Applying gabor filter to an image[11]

Wavelet transform [12] has also been used in face detection to decompose in image into sub bands to extract local information from the image both in frequency and space domain. The result of applying wavelet decomposition to an image is shown in fig. 2.

Figure. 2 Face images with wavelet decomposition [12]

Viola Jones method [13] uses Haar filters for face detection. The Viola Jones object detecting framework can be trained to detect a variety of object but it was primarily made for the problem of face detection[13]. It gained popularity due to it being open sourced. It is one of a kind algorithm proposed by Paul Viola and Michael Jones in 2001, which can be used to detect objects of varying size in real time. The viola Jones algorithm uses three techniques: It uses Haar-like features [14] for feature extraction.

AdaBoost [15] which is a machine learning technique is used to learn the features for object detection and cascaded classifiers as shown in fig. 3 are used to combine many features efficiently.

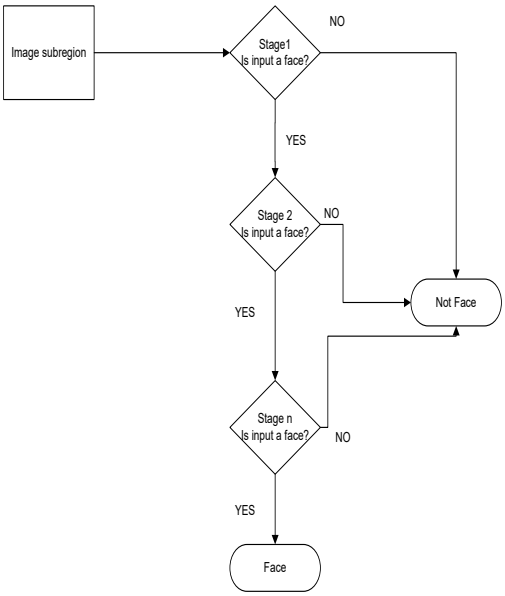


Figure. 3 Cascaded classifier for face detection

In the Viola Jones algorithm face detection is controlled by special trained scanning window classifiers. The Viola Jones object detecting model uses the fact that the central part of an eye is darker than the surrounding parts [16] as shown in fig. 4a. To detect the nose this model uses the fact that the central part of the nose is lighter than the surrounding nostril area(Dark-White-Dark) [17] as shown in fig. 4b. The lip detection method is based on RGB chromaticity diagram to separate lip color from other colors on the face by a simple effective colour segmentation technique[18].

(a) (b)

Figure 4a. Front View of human eye, Figure.5b Front view of human nose

II. CHECKS BASED ON FACIAL SYMMETRY TO IDENTIFY FACIAL FEATURES

The human face has a distinct vertical line of symmetry that passed through the middle of the face and it was this feature of the human face that was used to find the facial features. We use the following checks to find the facial features.

- If the human face is divided into four quadrants we can deduce that the left eye will be in the second quadrant.
- The right eye will be in the first quadrant.
- The vertical bisector of the nose will be the same as the vertical bisector of the face
- The vertical bisector of the mouth will be the same as the vertical bisector of the face.
- The mouth will be in the lower half of the horizontal bisector of the face.
- The eyes will be in the upper half of the horizontal bisector of the face.

The vertical and horizontal bisectors are as shown in fig. 5.

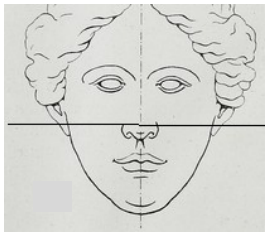


Figure. 5 Face bisectors

III. PROPOSED METHOD

The proposed method uses Viola Jones method to detect possible facial features and then it further uses the rules of facial geometry to select the best possible feature and eliminate wrongly detected features.

The new model first uses Viola Jones face detector method to detect a face in the image given. After which the Viola Jones object detector was used to detect possible nose, mouth and eyes regions. Once Viola Jones method detects possible nose, mouth and eyes region a series of checks as stated in the previous section were used to deduce the correct locations of the nose, mouth and eyes region.

A. Nose Detection

In recent research it was indentified that the nose is a very important feature that can be used for the recognition of a person [19], which makes the detection of an accurate nose in an image vital. In the proposed method firstly the nose regions were detected using cascade object detector which uses the Viola Jones algorithm. In experimentation it was observed that usually this method will detect multiple noses, which will include one true nose and multiple false noses. The algorithm shown in table I will be used to detect the correct nose. First the center of the face and all the noses detected are located. The first check is that the nose box should be inside the face box and then based on center of the nose boxes the correct nose is selected as the one which is closest to the center of the face.

TABLE I. ALGORITHM TO DETECT MOUTH AND NOSE

1. Read image
2. F= Detected face
3. N= Detected Noses
4. M=Detect Mouths
5. For i = 1 to sizeof(N)
    a. If N(i) box is located inside F
        i. If the N(i) box centre has minimum distance from the face box center
            1. correct nose = N(i)
6. For i = 1 tosizeof(M)
    a. If M(i) box is located inside F
        i. If the M(i) is on the correct side of the horizontal bisector
            1. If the M(i)'s vertical bisector has minimum distance from the face vertical bisector
                a. correct mouth = M(i)

cascaded classifiers of the Viola Jones method. Geometric checks are applied on the mouth regions detected by viola Jones. The checks as shown in table I include that the center of the mouth box should be below that of the nose box and that the mouth should be in the lower half of the face and that the center of the mouth box should be closest to the vertical intercept of the face.

C. Left and Right Eye Detection

The cascaded object detector of Viola Jones can be used to either detect the left and right eye separately or as a pair. Possible left eyes are first detected using the Viola Jones algorithm, which gives multiple eyes. This algorithm then chooses the left eye to be the one which is located in the upper half and left side of the face. Similar steps are taken to detect the right eye. The algorithm is shown in table II.

TABLE II. ALGORITHM TO DETECT LEFT AND RIGHT EYE

1) N=Detected right eyes
2) M= Detected left eyes
3) For i = 1 to sizeof(N)
   a) If N(i) box is located inside F
      i) If N(i) is on the correct side of the horizontal bisector
         (1) If N(i) is on the correct side of the vertical bisector
            (a) correct right eye = N(i)
4) For i = 1 to sizeof(M)
   a) If M(i) box is located inside F
      i) If M(i) is on the correct side of the horizontal bisector
         (1) If M(i) is on the correct side of the vertical bisector
            (a) correct left eye = M(i)

The final result by applying the algorithms for nose, mouth, left and right eye detection is shown in fig. 6.

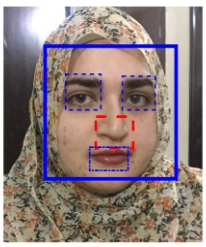


Figure 6. Facial Feature Detection using proposed method

The Viola Jones cascaded object detector algorithm and the proposed method were simulated in Matlab and run on a core i5 processor. 200 images were taken from the extended Yale face database B [20] that includes grey scale images of 28 different subjects under different lighting condition, both genders and different ethnicities. All the images are of a front facing person. 50 test images were taken from the FASSEG dataset [21] that include coloured images of 50 different subjects under different lighting condition, both genders and different ethnicities. All the images are of a front facing person. All the images of test subjects were run through both the Viola Jones and proposed method in Matlab. Results were obtained for nose, mouth, left eye and right eye detections for both Viola-Jones method and proposed method. Viola Jones was trained using 20 cascaded stages, a minimum true positive rate of 0.995. Merge threshold was set to 16 for mouth detection and default value of 4 for nose, left eye and right eye detection. The merge threshold was set at a higher value for mouth detection due to high number of false positives.

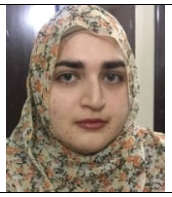
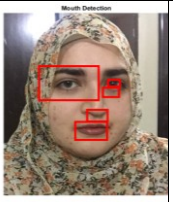
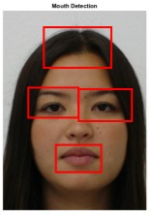
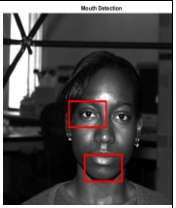
II. RESULT AND DISCUSSION

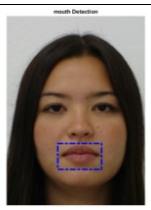
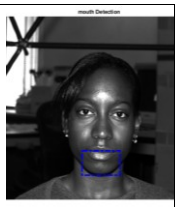
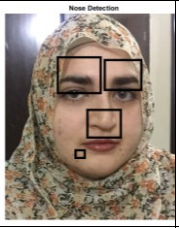
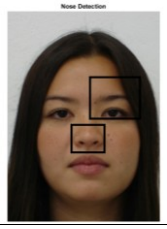
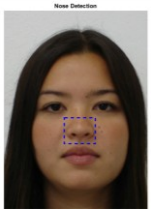
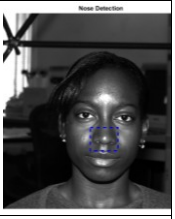
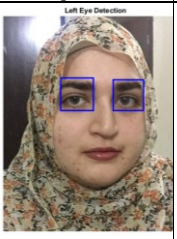
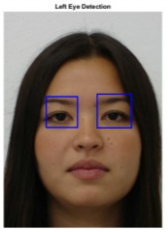
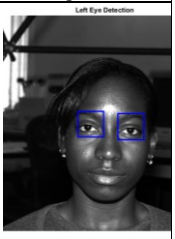
The proposed algorithm overcomes the short comings of Viola-Jones algorithm just by introducing minor additional processing. The algorithm uses human facial geometry to detect facial features [22].

Experimental result shows that the proposed method works considerably better in detecting the nose, mouth, left eye and right eye on both the datasets than just using cascaded object detector. For the FASSEG dataset out of 50 images Viola Jones was able to detect the one correct nose without any false nose detections in 27 cases while the proposed algorithm was able to find the correct nose in all the 50 test images. For the Extended Yale face database B Viola Jones was able to detect the one correct nose without any false nose detections in 88 cases while the proposed algorithm was able to find the correct nose in all the 200 test images

Viola Jones method detected on average two to three false mouths in all test cases in both the datasets while the proposed method detected the correct mouth in 46 of the 50 test images for the FASSEG dataset and 170 of the 200 test images for the Extended Yale face database B. Table III shows the result of the facial feature detection by Viola-Jones and the proposed method using the FASSEG dataset and extended Yales face database B. As can be seen in table 3 the proposed method increases the accuracy of detection in both coloured and gray scale images. As shown in table III, the proposed algorithm performs considerably better than Viola-Jones algorithm. The detection accuracy of Viola Jones may increase if the merge thresholds are adjusted but, fine tuning the merge threshold for different images is not feasible for real-time detection.

TABLE III . COMPARISON BETWEEN VIOLA-JONES AND PROPOSED ALGORITHM

	1	2	3
Original image			
Mouth detection by Viola Jones method			
	1 mouth detected 4 false positive	1 mouth detected 3 false positive	1 mouth detected 1 false positive

Mouth detection by Proposed method			
	1 mouth detected 0 false positive	1 mouth detected 0 false positive	1 mouth detected 0 false positive
Nose detection by Viola Jones method			
	1 nose detected 3 false positive	1 nose detected 1 false positive	1 nose detected 1 false positive
Nose detection by Proposed method			
	1 nose detected 0 false positive	1 nose detected 0 false positive	1 nose detected 0 false positive
Left eye detection by Viola Jones			
	1 Left eye	1 Left eye detected	1 Left eye

The cascaded object detector based on Viola Jones cannot differentiate between the left and right eye in a front facing image and on average detects 1-2 false left and right eyes in an image. The proposed method was able to detect all the correct right eyes for the FASSEG dataset in all the 50 test cases and detect the correct left eye in 48 of the 50 images. These statistics are shown in fig. 7 for the FASSEG dataset.

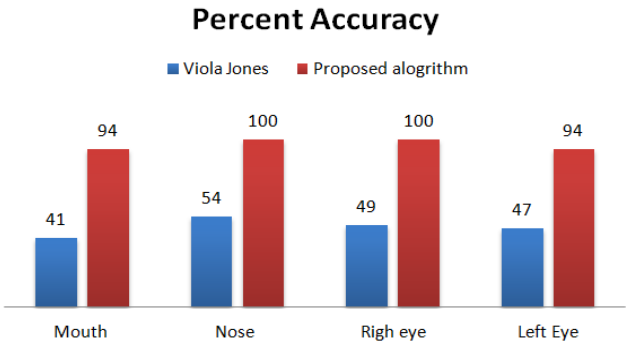
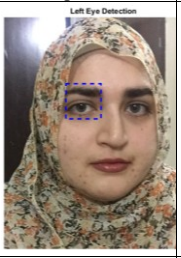
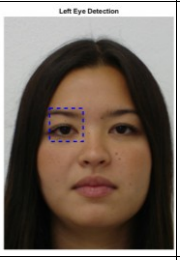
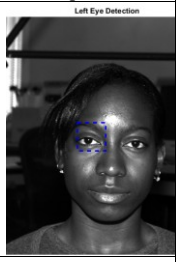
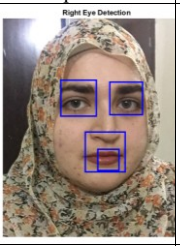
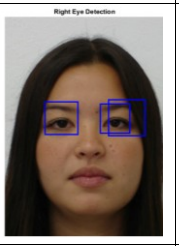
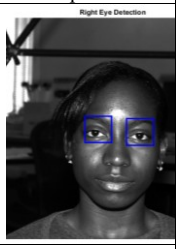
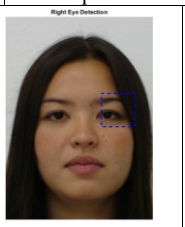
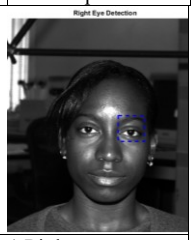


Figure 7. Comparison of Facial Feature Detection Accuracy for the FASSEG dataset

	detected 1 false positive	1 false positive	detected 1 false positive
Left eye detection by Proposed method			
	1 Left eye detected 0 false positive	1 Left eye detected 0 false positive	1 Left eye detected 0 false positive
Right eye detection by Viola Jones			
	1 Right eye detected 3 false positive	1 Right eye detected 2 false positive	1 Right eye detected 1 false positive
Right eye detection by Proposed method			
	1 Right eye detected 0 false positive	1 Right eye detected 0 false positive	1 Right eye detected 0 false positive

The images of subject 2 and 3 have been taken from the FASSEG Database and Extended Yale Face Database respectively

The proposed method was able to detect all the correct right eyes for the extended Yale face dataset in 198 of the 200 test cases and detect the correct left eye in 190 of the 200 images. These statistics are shown in fig. 8 for the Yale dataset.

The proposed method can be used for human facial feature detection for recognition in surveillance videos, to detect human emotions, access control, etc.

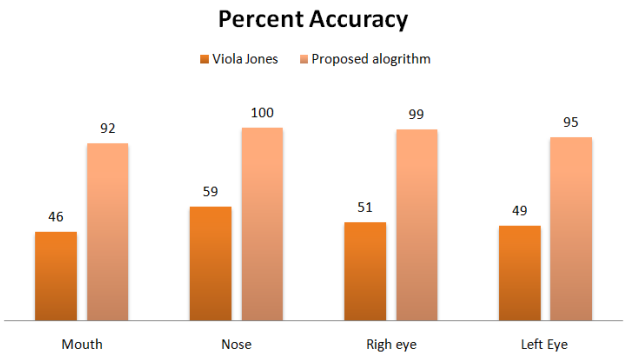


Figure 8. Comparison of Facial Feature Detection Accuracy for the Extended Yale Face database B

The proposed method in combination with Viola Jones algorithm works well on both coloured and gray-scale images. The proposed method also works well with different ethnicities and skin colour.

III. Conclusion and Future Work

In this paper we present a novel facial feature detection model which uses a combination of Viola-Jones algorithm and the proposed algorithm. This method has considerably increased the accuracy of detecting facial features in an image with complex background over just using Viola-Jones object detecting algorithm.

As Viola-Jones method does not work well with low intensity images so, in the future effort will be made to make the algorithm functional in variable lighting conditions. Efforts will also be made for the algorithm to also work on images with multiple persons.

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